Thermodynamic

2026-1

NEDHER SÁNCHEZ RAMÍREZ

NAUDY LOPEZ

Work-Heat-First Law_Control mass_S_{5_1}

UTEC
UNIVERSIDAD DE INGENIERÍA Y TECNOLOGÍA

Recomendaciones generales:

- Leer antes de clase y entender los conceptos o preguntar si es necesario.
- Practicar bastante:
  - *Ejercicios de clase
  - *Asesorías
  - *Ejercicios del libro resueltos y los de final de capitulo
- Los quizzes virtuales y gradescope úsenlos para aprender de forma honesta (se puede inferir).
- Tengan grupos de estudio y apóyense mutuamente.
- Crear sus propias notas estudio y formulario.
- Son 4 horas de clase en la semana (asistir y ser puntuales, perder alguna es atrasarse mucho)
- Cada hora de clase son 3 horas de estudio por fuera mínimo.
- En la ppt de la semana 1 están todos los links claves para el curso.

Thermodynamics _ Evaluation

COMPONENTE	%
PARCIAL	20
FINAL	30
C	50
APROBACIÓN: 11/20	

SEMANA 1	TAREA VIRTUAL	SE CALIFICA AUTOMATICO NO NECESITA PROCEDIMIENTO
SEMANA 2	TAREA VIRTUAL	
SEMANA 3	TAREA VIRTUAL	.
SEMANA 4	TAREA INDIVIDUAL 1 + EVALUACION_ AULA1	TAREA INDIVIDUAL: Esta parte incluye subir un archivo con la solución EVALUACION_ AULA: SEMANAS 1-2
SEMANA 5	TAREA VIRTUAL+ EVALUACION_ AULA2	EVALUACION_ AULA: SEMANAS 1-3
SEMANA 6	TAREA VIRTUAL+TAREA INDIVIDUAL 2	
SEMANA 7	TAREA VIRTUAL+ EVALUACION_ AULA3	EVALUACION_ AULA: SEMANAS 1-6
SEMANA 8	PARCIAL	
SEMANA 9	EVALUACION_ AULA4+TAREA INDIVIDUAL 3 +Tarea grupal 1	EVALUACION_ AULA: SEMANAS 1-8
SEMANA 10	TAREA VIRTUAL	
SEMANA 11	TAREA VIRTUAL	
SEMANA 12	TAREA VIRTUAL+ EVALUACION_ AULA5	EVALUACION_ AULA: SEMANAS 1-11
SEMANA 13	TAREA VIRTUAL+TAREA INDIVIDUAL 4 + Tarea grupal 2	
SEMANA 14	TAREA VIRTUAL+EVALUACION_ AULA6	EVALUACION_ AULA : SEMANAS 1-13
SEMANA 15		
SEMANA 16	FINAL	

***LAS TAREAS VIRTUALES O LOS GRADESCOPE (TAREA INDIVIDAL) se abren lunes 2pm y se cierran sábado media noche. La tarea virtual se presenta hasta un máximo de 3 veces.**

EVALUACION_ AULA: es un quiz de 20 min aprox. en aula.

Session 9-10: Describe the concepts of energy, heat and work and relate them to the principle of conservation of energy (first law of thermodynamics).

Thermodynamics is built on 3 empirical laws

0^{th} Law $\Rightarrow$ Defines Temperature (T)

1^{st} Law $\Rightarrow$ Defines Energy (E,U)

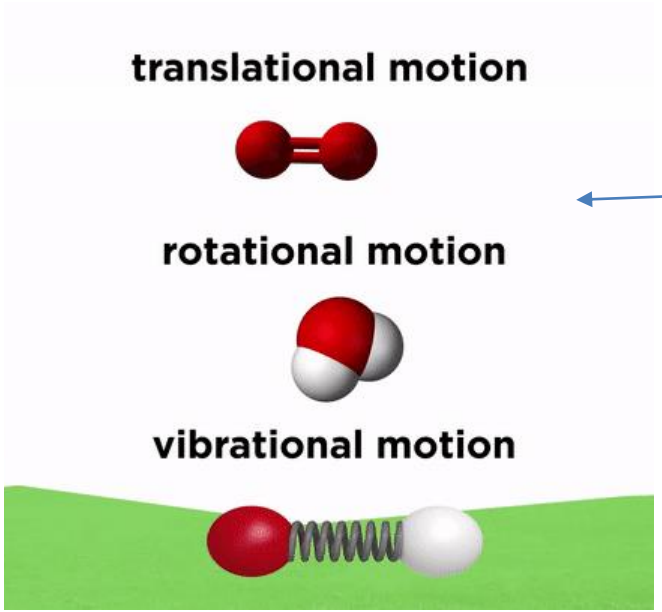
2^{nd} Law $\Rightarrow$ Defines Entropy (S)

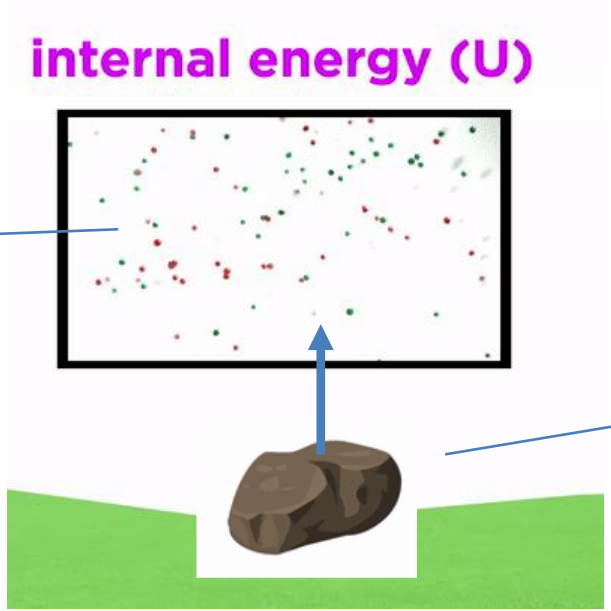
TOTAL ENERGY

- Since a system is a quantity of matter and it has energy, it is logical to think about quantifying it.

TOTAL ENERGY

- Since a system is a quantity of matter and it has energy, it is logical to think about quantifying it.





-Pure substance
-Gases

ENERGY

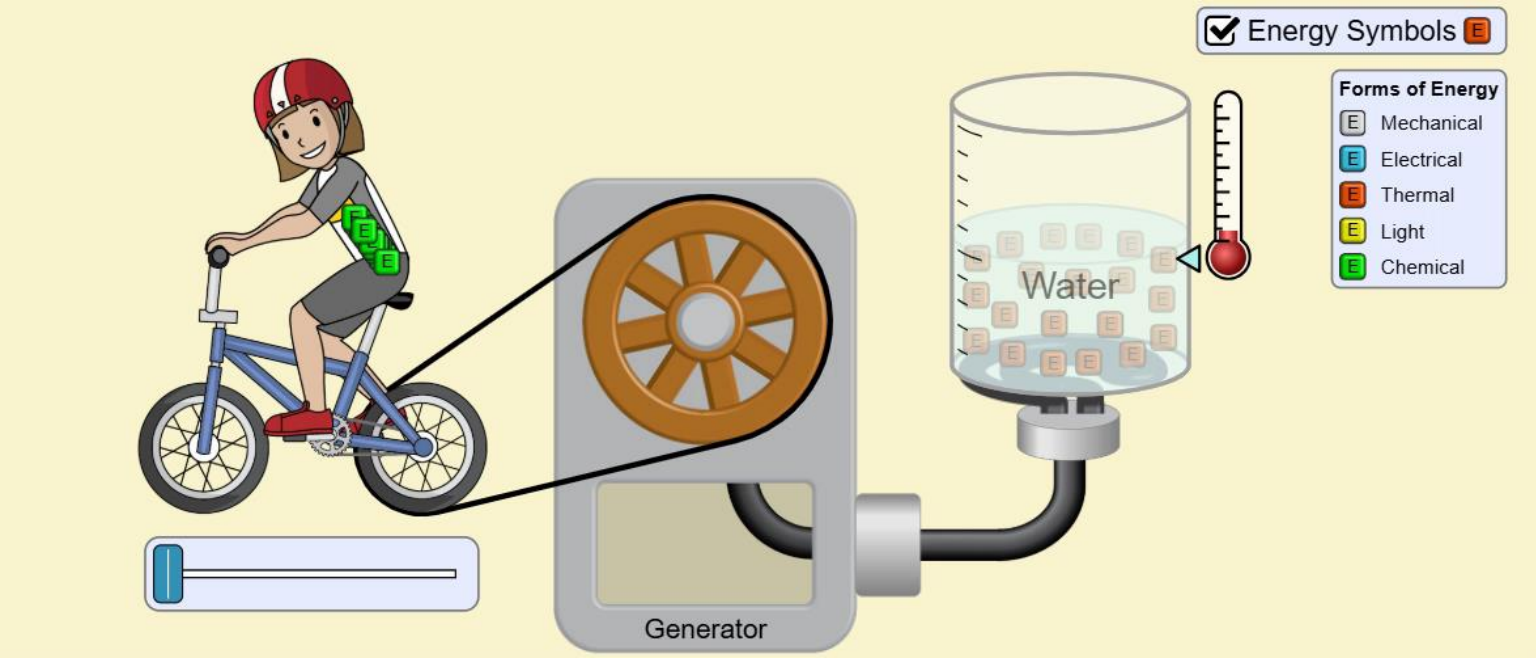
A macroscopic amount of mass can possess energy in the form of **internal energy** inherent in its internal structure, **kinetic energy** in its motion, and **potential energy** associated with external forces acting on the mass (g).

$$E = \text{Internal} + \text{Kinetic} + \text{Potential} = U + \text{KE} + \text{PE}$$

$$e = E/m = u + ke + pe = u + {}^{1}\!/_{2}V^{2} + gz$$

NEARPOD

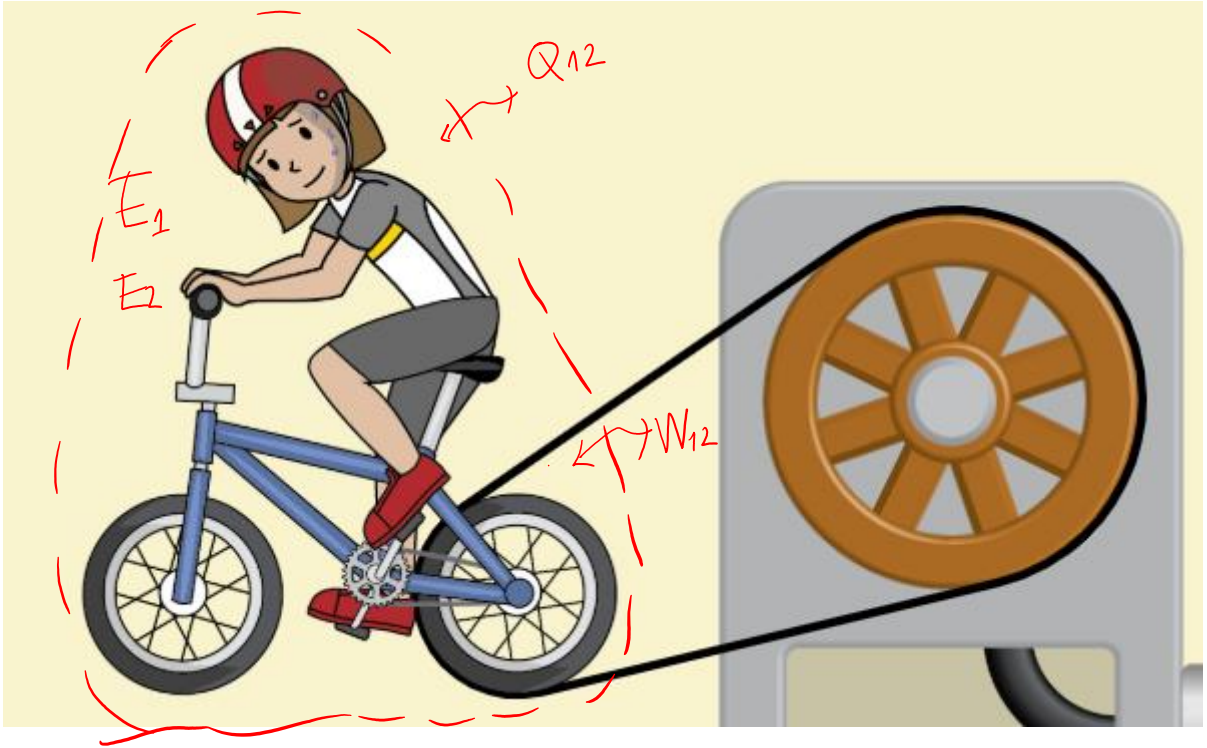
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA



UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

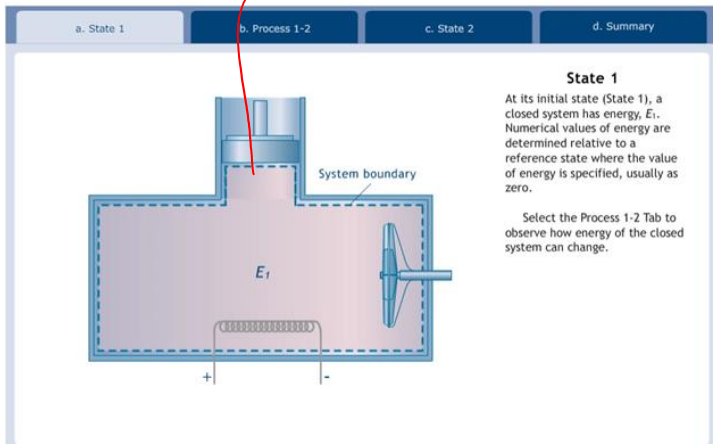
$$\Delta E = Q_{12} - W_{12}$$

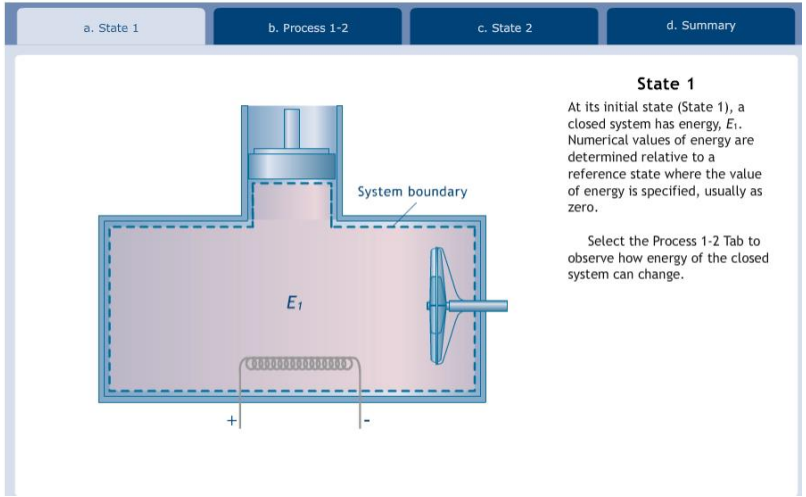
Q_{12}, W_{12} son consecuencia del proceso.

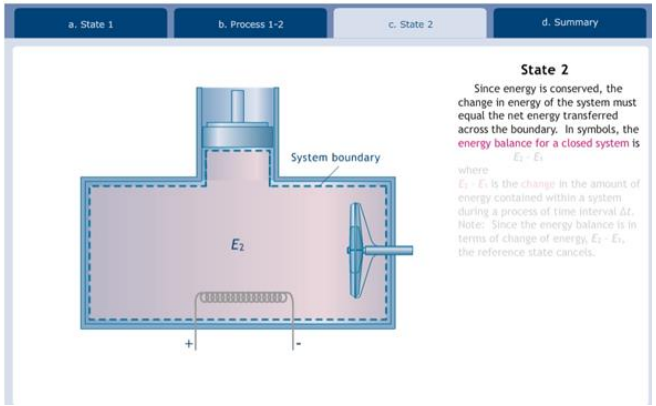


UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

sistema { • Gas ideal o mezcla
• H_2O .. ETC







Balance de Energía en el sistema (proceso 1-2)

$$\Delta U = Q_{12} - W_{12}$$

Q_{12}: NETO

W_{12}: NETO

$$W_{12} = W_{pv} + W_e + W_{eje}$$

Los calcularemos analíticamente

Thermodynamics?

Thermo_ heat _ dynamics _ movement

E, U

Thermodynamics involves the storage, transformation, and transfer of energy.

Q,W, m (open system)

The first law relates all these variables, “**m**” appears only for open system (later)

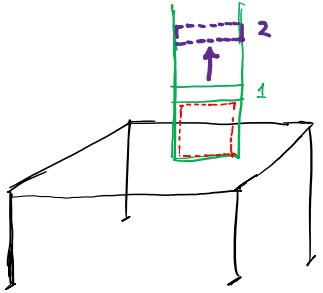
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Energy Accounting: Energy Balance for Closed Systems

[*change* in the amount of energy contained within a system during some time interval] = [*net* amount of energy transferred *in* across the system boundary by *heat* transfer during the time interval] − [*net* amount of energy transferred *out* across the system boundary by *work* during the time interval]

$$E_2 - E_1 = Q - W$$

$$\Delta \text{KE} + \Delta \text{PE} + \Delta U = Q - W$$



Energy Accounting: Energy Balance for Closed Systems

$$\Delta \text{KE} + \Delta \text{PE} + \Delta U = Q - W$$

$$\Delta E = \Delta U + \Delta \text{KE} + \Delta \text{PE}$$

$$\Delta U = m(u_2 - u_1)$$

$$\Delta \text{KE} = \tfrac{1}{2} m(V_2^2 - V_1^2)$$

$$\Delta \text{PE} = mg(z_2 - z_1)$$

Stationary Systems

$z_1 = z_2 \rightarrow \Delta \text{PE} = 0$

$V_1 = V_2 \rightarrow \Delta \text{KE} = 0$

$\Delta E = \Delta U$

For stationary systems, $\Delta \text{KE} = \Delta \text{PE} = 0$; thus $\Delta E = \Delta U$.

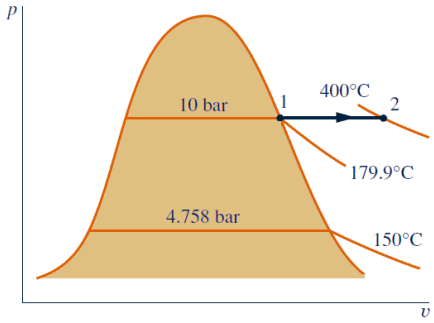
$$\Delta E = Q_{12} - W_{12}$$

$$\Delta U = Q_{12} - W_{12}$$

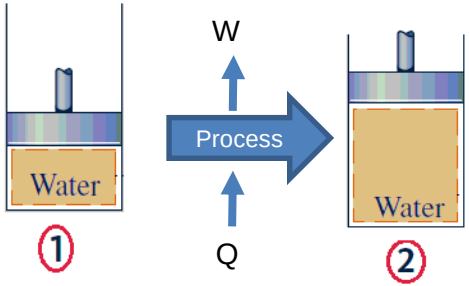
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Work-Heat-First Law

Water contained in a piston–cylinder assembly undergoes one processes from an initial state where the pressure is 10 bar and the temperature is 179.9 ºC to 10 bar and 400 ºC (state 2).



POLL



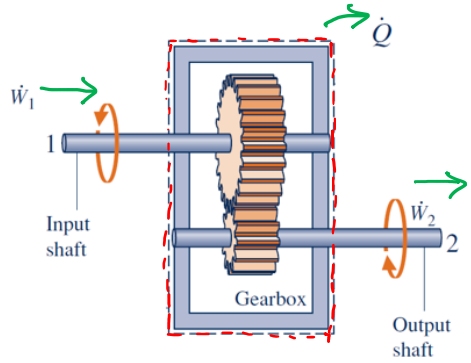
$\Delta E = Q_{12} - W_{12}$

B.E del proceso que ocurre entre

The energy balance in differential form is: $dE = \delta Q - \delta W$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Energy Accounting: Energy Balance for Closed Systems



The instantaneous **time rate form of the energy balance** is :

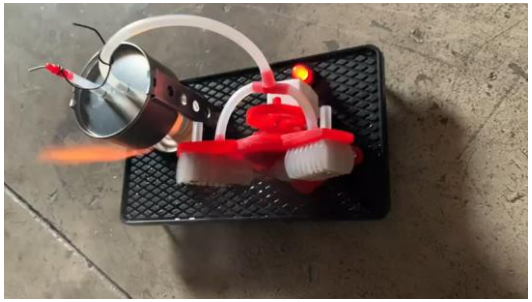
$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

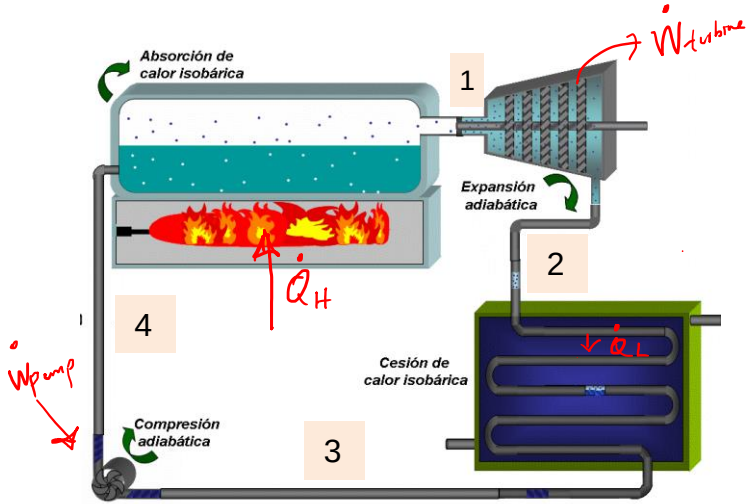
Ejemplo 2.4 Shapiro.

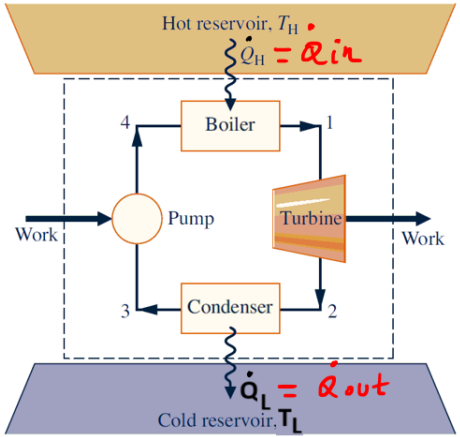
Cycles

Work-Heat-Firts Law

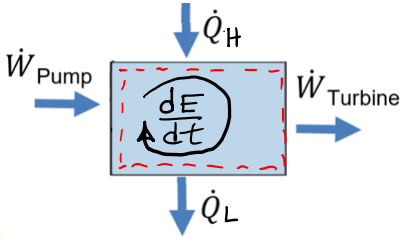
Remembering the concept of control mass from week 1.

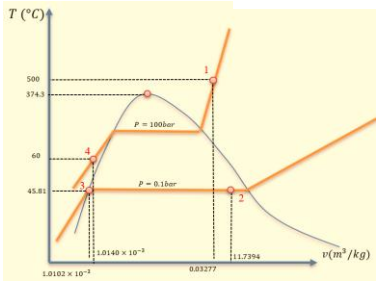






CONTROL MASS

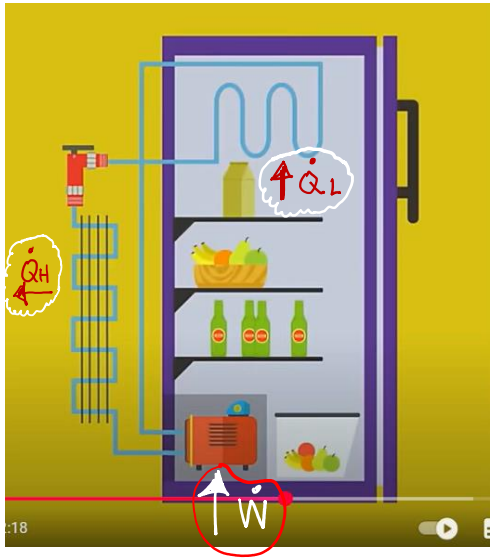


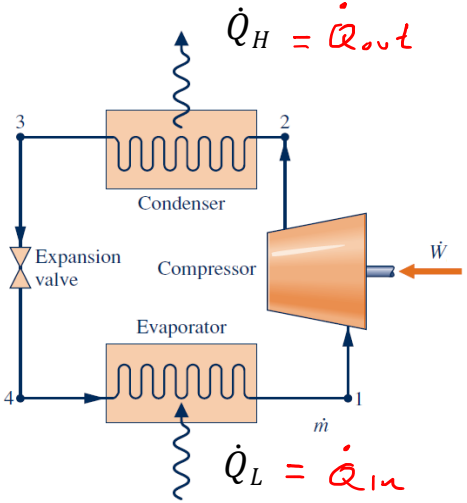


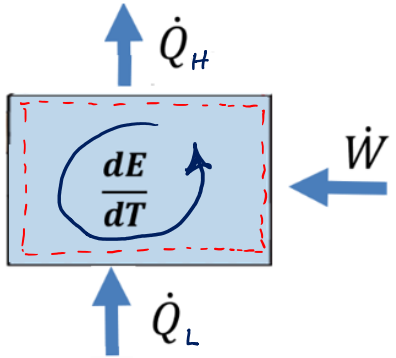
$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

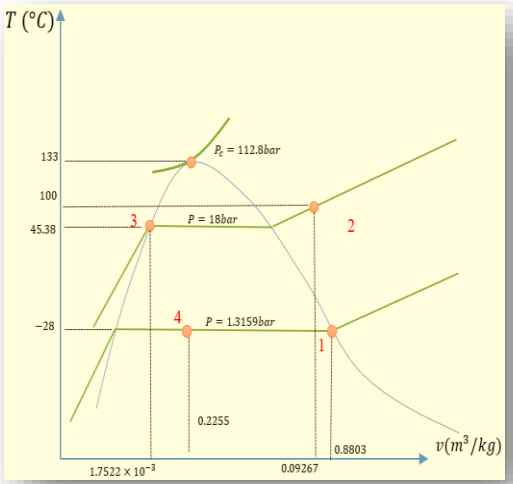
Refrigeration cycle







$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

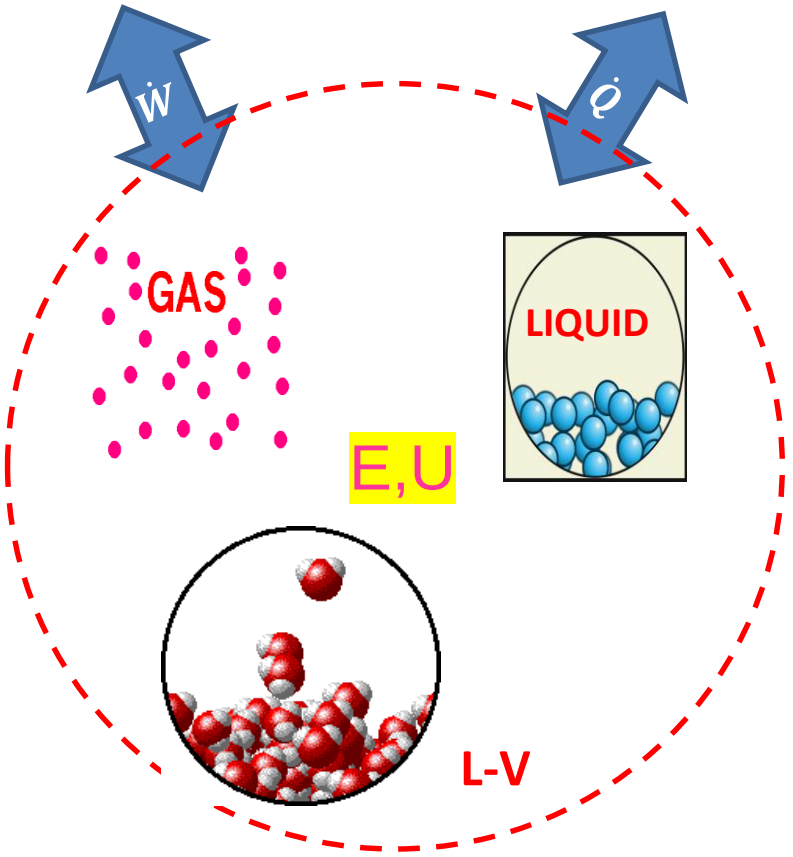


UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

POLL

Mass control

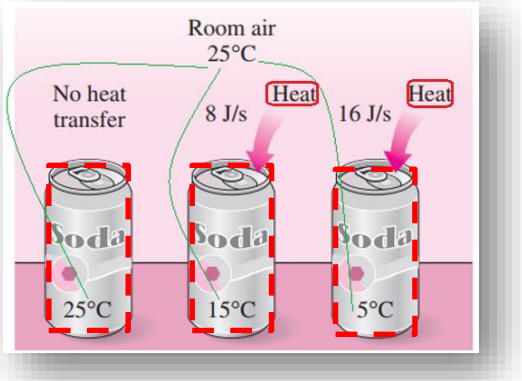
Work-Heat- First Law



* Energy can cross the boundary of a system in two distinct forms: ***heat*** and ***work***

a) Heat

Heat is defined as *the form of energy that is transferred between two systems (or a system and its surroundings) by virtue of a temperature difference:*

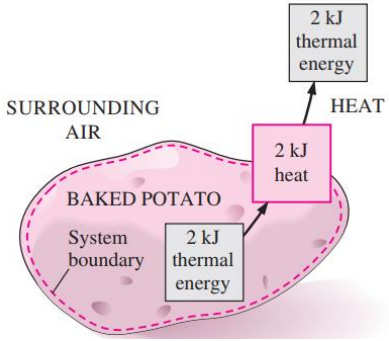


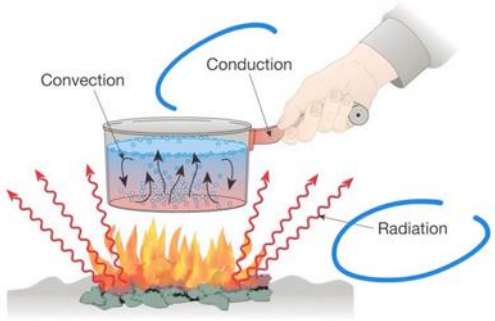
HOW CAN A SYSTEM EXCHANGE ITS ENERGY?

a) Heat

Heat is energy in transition. It is recognized only as it crosses the boundary of a system:

Work too





Heat transfer *per unit mass* of a system is denoted $\boldsymbol{q}$ and is determined from:

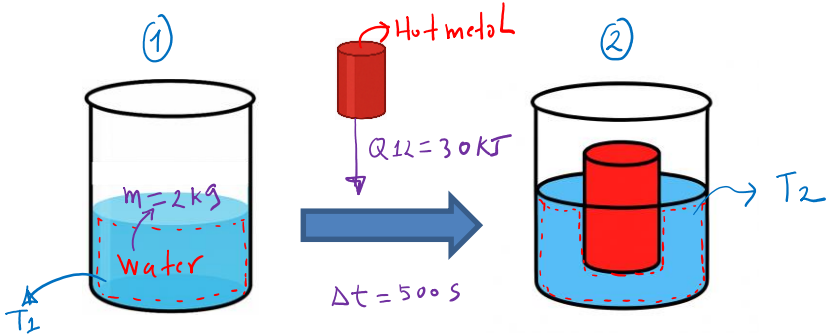
$\dot{Q}$ (kJ/s) or kW

$$Q = \int_{t_1}^{t_2} \dot{Q}\, dt \quad (\text{KJ})$$

$$q = \frac{Q}{m} \qquad (\text{kJ/kg})$$

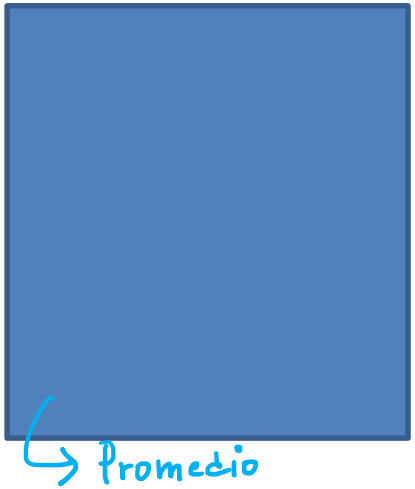
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

WHO I CAN RELATE Q, q AND Q and Q



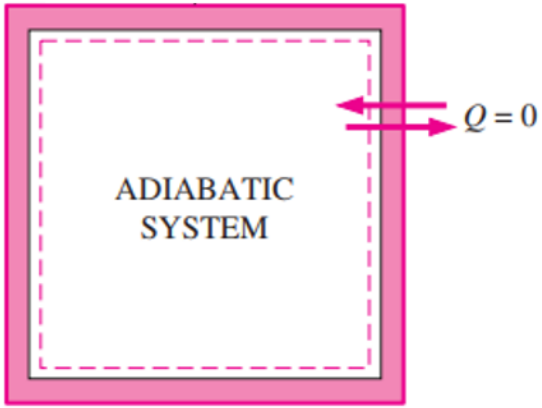
q ??

$\dot{Q}$??



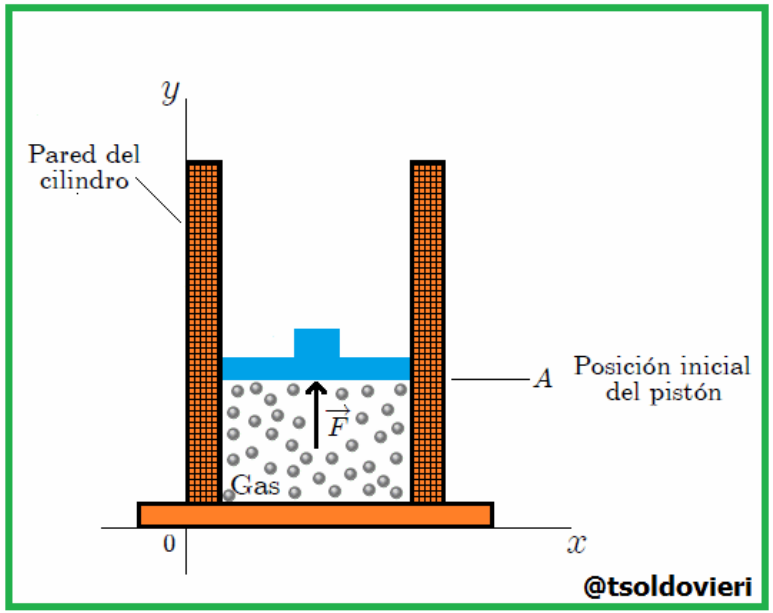
HOW CAN A SYSTEM EXCHANGE ITS ENERGY?

a) Heat_ adiabatic



During an adiabatic process, a system exchanges no heat with its surroundings.

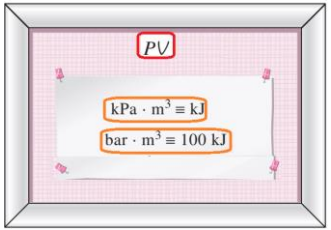
- **DEFINITION: b) Work -- is done by a system (on its surroundings) if the sole effect on everything external to the system could have been the raising of a weight**



https://hive.blog/stem-espanol/@tsoldovieri/gas-ideal-gas-real-y-el-trabajo-realizado-por-un-gas

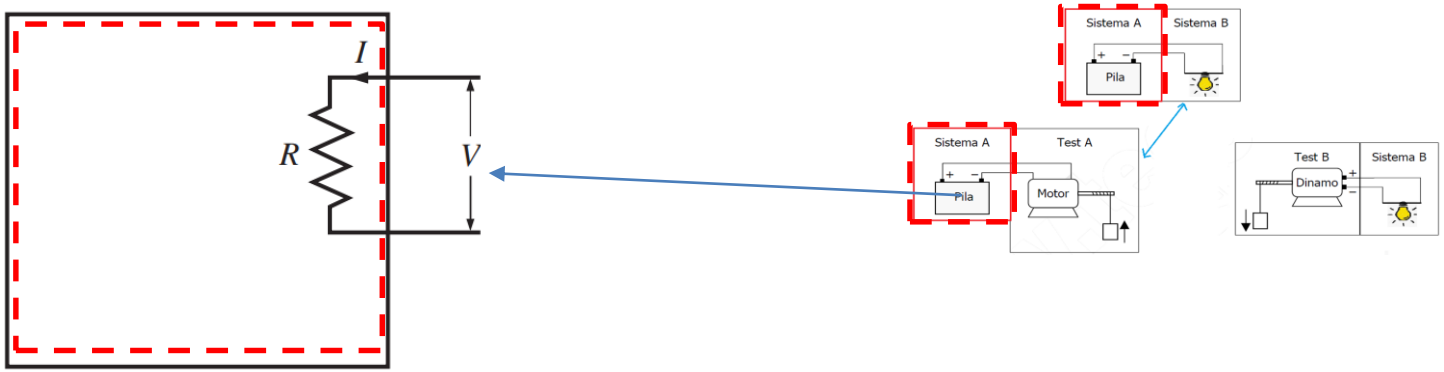
$$\delta W = PA\,dx \;\rightarrow\; \delta W = P\,dV \;\rightarrow\; W = \int_1^2 P\,dV$$

sys-t



UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

- **DEFINITION: Work -- is done by a system (on its surroundings) if the sole effect on everything external to the system could have been the raising of a weight**



When both **V** and I remain constant during the time interval Δt

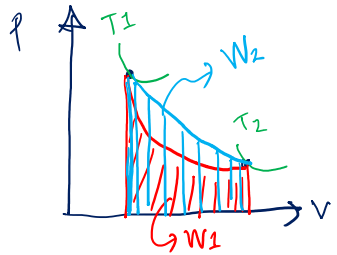
$$\dot{W}_e = \mathbf{V}I \quad (\mathrm{W}) \quad (\mathrm{J/s} = \mathrm{W})$$

$$W_e = \mathbf{V}I\,\Delta t \quad (\mathrm{J})$$

Q and W are not state functions!

$$\Delta U = Q - W$$

$$dU = \delta Q - \delta W$$

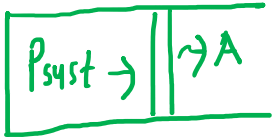


dependen de La trayectoria

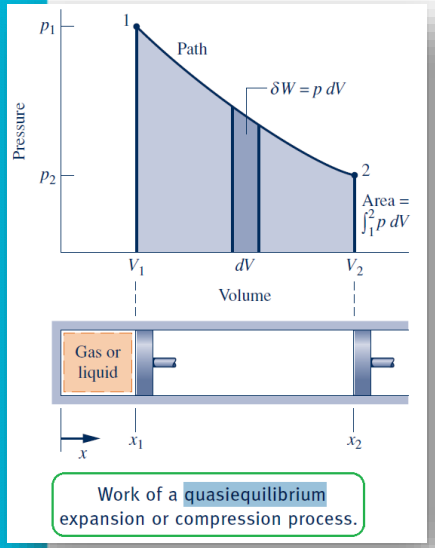
Si es un Gas ideal ΔU es $F_n(T_1, T_2)$ siempre

pero W, Q dependen de La trayectoria

The Moving Boundary Work (PV -Work)



$$\delta W = PAdx \quad \text{(Syst)} \quad \Rightarrow \quad \delta W = PdV \quad \Rightarrow \quad W = \int_1^2 PdV$$



Work of a quasiequilibrium expansion or compression process.

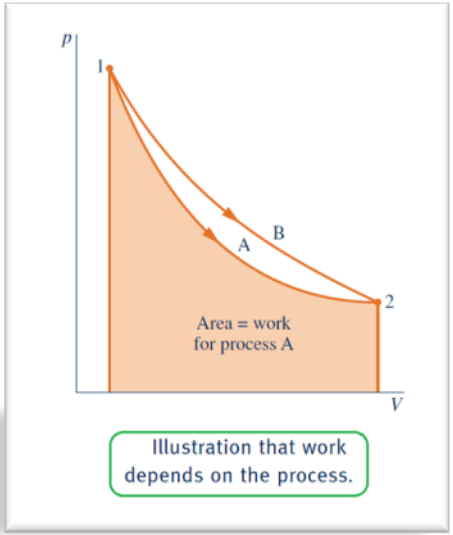
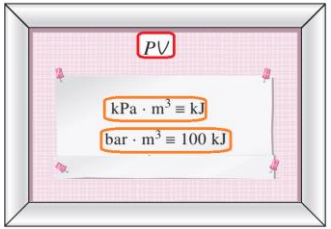


Illustration that work depends on the process.

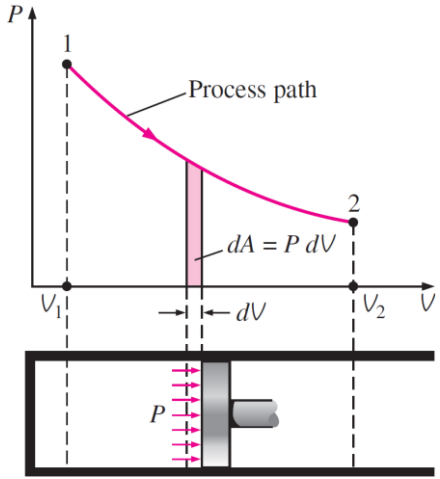


UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

The Moving Boundary Work (PV -Work)

In Mechanics: $W = \int_1^2 \delta W = \int_1^2 \vec{F} \cdot d\vec{x}$

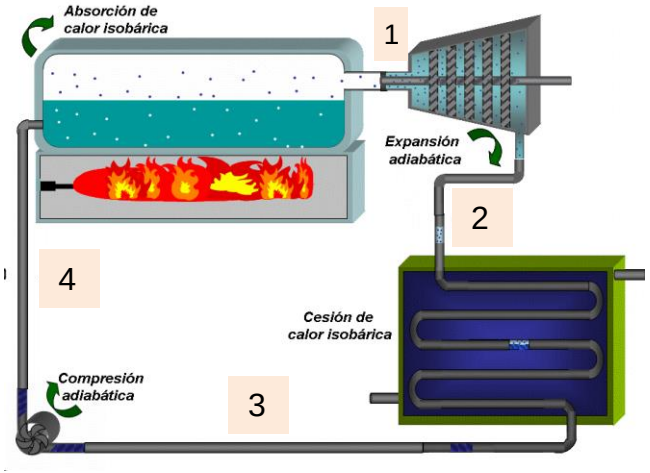
Moving Boundary Work: $\delta W = PAdx \rightarrow \delta W = PdV \rightarrow W = \int_1^2 PdV = W_{boundary} = W_b$

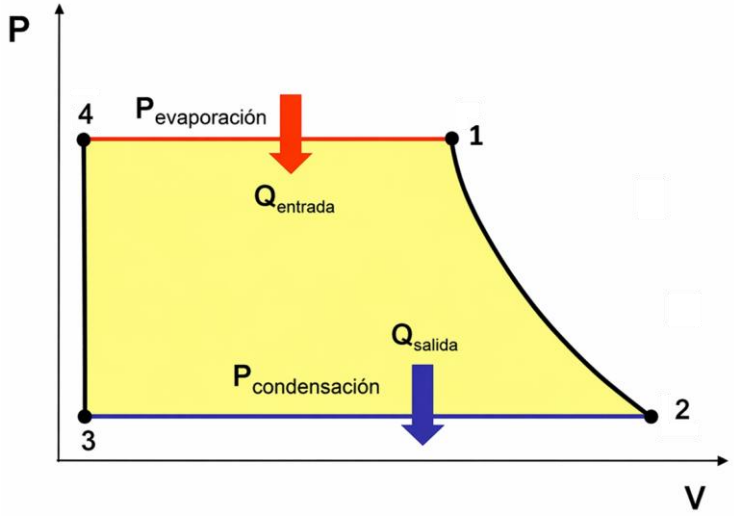


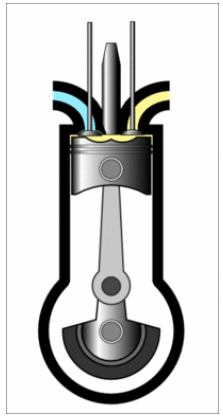
If the process is quasistatic (or reversible), the pressure within the system can be considered uniform at each instant. Therefore, a single pressure value is representative of the system, and the boundary work can be written as above

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Boundary Work: Net Work per Cycle







- For path functions $\oint \delta W = \oint P dV \neq 0$

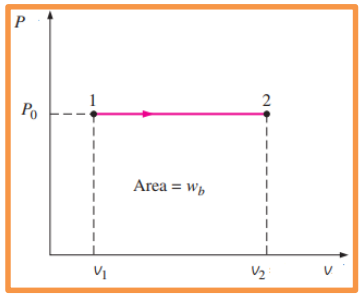
- This enables cyclic devices (car engines, power plants,……) to produce net work.

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

The Moving Boundary Work (PV -Work)_Quasistatic

In determining the integral: $W = \int_1^2 P\,dV$ (sys)

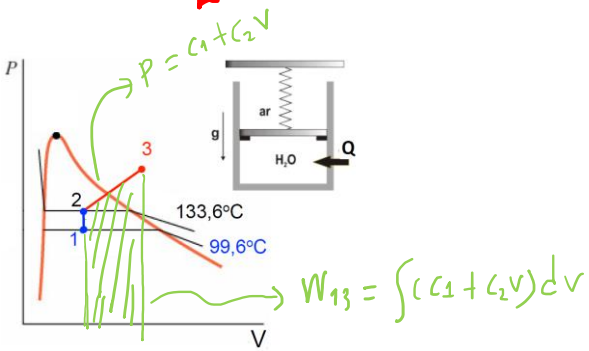
Isóbaro

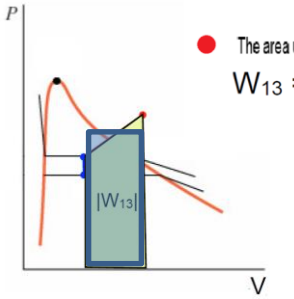


Analítico
Geométrico

★ Relation P-V obtained mathematically or for a model or for a process.

Lineal





- The area under the process curve (a trapezoid) is determined to be:

$W_{13} = (P_3+P_2)(V_3-V_2)/2 = 175kJ$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

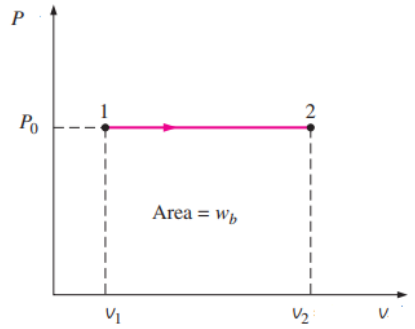
Boundary Work for ***isochoric process***

- **Isochoric process -- dV = 0**

- **Heating or cooling at constant volume.**

$$W_b = \int_1^2 PdV = 0$$

Boundary Work for a Constant-Pressure Process



$$W_b = \int_1^2 P\,dV = P_0 \int_1^2 dV = P_0(V_2 - V_1)$$

V volume i.e. m^3

$kPa \cdot m^3 = kJ$

$$W_b = mP_0(v_2 - v_1)$$

v specific volume i.e. m^3/kg

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Ideal Gas Law

- To turn a proportionality into an equation, insert a constant:

$$PV = n\bar{R}\,T$$

Where "$\bar{R}$ " is the universal gas constant. V volume i.e. m^3.

n or N = m/M (mass/molar mass)

$$Pv = (\bar{R}/M)T,$$

v specific volume i.e. m^3/kg; **"$\bar{R}$ /M "= R_g =R=gas constant**

Boundary Work: Isothermal Compression of an Ideal Gas

$$P_1V_1 = P_2V_2 = C = m\bar{R}/M\,T_0$$

$PV = m\,\bar{R}/M\,T$

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-1}\,dV = PV\ln\left(\frac{V_2}{V_1}\right)$$

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-1}\,dV = PV\ln\left(\frac{V_2}{V_1}\right)$$

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-1}\,dV = m\bar{R}/M\,T_0\ln\left(\frac{V_2}{V_1}\right)$$

Boundary Work: Polytropic Process

$$PV^n = C \qquad C = P_1V_1^n = P_2V_2^n$$

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-n}\,dV = C\frac{V_2^{-n+1} - V_1^{-n+1}}{-n+1} = \frac{P_2V_2 - P_1V_1}{1-n} \quad \text{(kJ)} \qquad n \neq 1$$

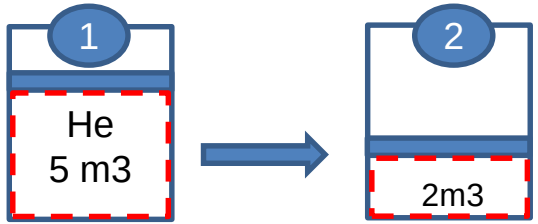
For an ideal gas ($PV = m\bar{R}/\mathrm{M}T$)

$$W_b = \frac{m\bar{R}/\mathrm{M}(T_2 - T_1)}{1-n} \quad \text{(kJ)} \qquad n \neq 1$$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

EXAMPLE 1: The volumen of 1 kg of helium (ideal gas) in a piston-cylinder device is initially 5 m^3. Now helium is slowly (reversible) compresed to 2 m^3 while its pressure is mantained constant at 180 kPa. Determine the initial and final temperaturas [K] of helium as well as the work required to compress it [kJ].

Assumptions The process is quasi-equilibrium.
Properties For helium is $\bar{R}/M$ = 2.0769 kJ/kg.K (Table A-1)



The **initial** sate:

$PV = m(\bar{R}/M)T$

1 **kPa · m3** = 1 kJ.

Using the ideal gas equation:

$$T_1 = \frac{P_1 * V_1}{m * \bar{R}/M} = \frac{(180kPa)(5\,m^3/kg)}{1.0\ kg\ * 2.0769\ kJ/kgK} = 433.3381\ K$$

Final state:

Since the pressure stays constant:

$P_1 = 180$ kPa, 2.0769

$P_2 V_2 = mRT_2$

V_2: 2 m^3, m: 1 kg

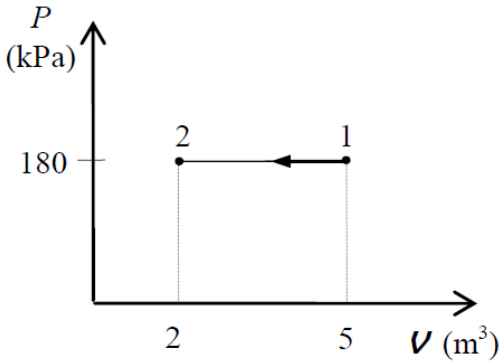
$$T_2 = 173.3353\ K$$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

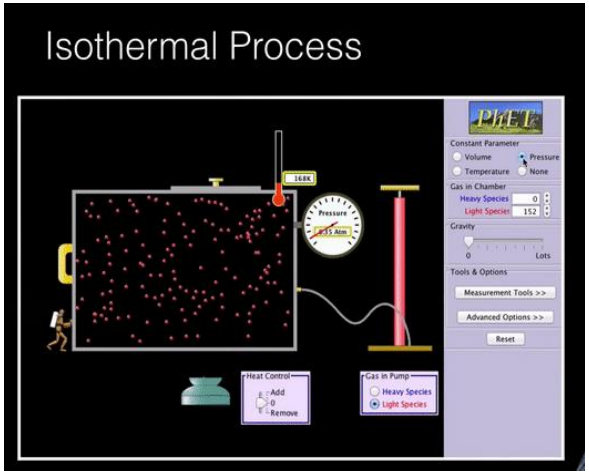
And the work integral expression gives:

$$W_b = \int_1^2 PdV = P(V_2 - V_1) = 180kPa.(2-5)m^3$$

$$W_b = -540\ kJ$$

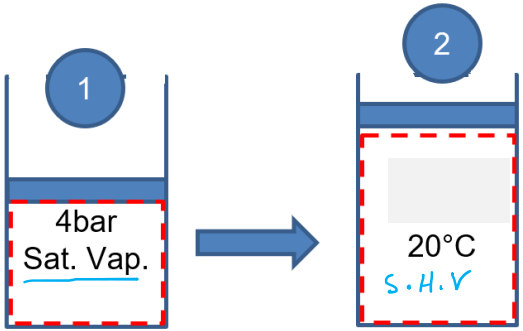


We will se later that **W < 0** imply that work is done on the system



UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

EXAMPLE 1.3: 4 kg of ammonia in a piston–cylinder assembly undergoes a quasistatic constant pressure process. The initial state is saturated vapor at 4 bar, and the final temperature is 20°C. Determine (a) the volume change, in m^3, and (b) the work for the process, in kJ.



Specific volume: state (1)

TABLE A-14

Properties of Saturated Ammonia (Liquid–Vapor): Pressure Table

Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g	Press. bar
4.00	−1.90	1.5597	0.3094	170.55	1316.12	171.18	1268.71	1439.89	0.6776	5.3548	4.00

state (2)

TABLE A-15

(*Continued*)

T °C	v m^3/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	$p = 4.0$ bar $= 0.40$ MPa ($T_{sat} = -1.90$°C)			
20	0.34129	1358.81	1495.33	5.5515

$$\Delta V = m(v_2 - v_1) = 4 \times (0.34129 - 0.3094) = \mathbf{0.1276\ m^3}$$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Considering the process reversible (quasistatic process):

$$W = \int PdV = P(V_2 - V_1)$$

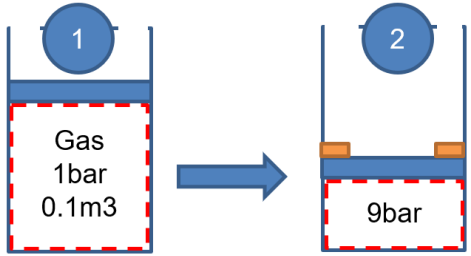
$$W = P\Delta V$$

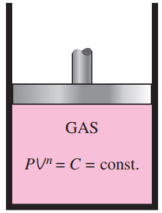
$$W = 400\ kPa \times [\mathbf{0.1276}]m^3$$

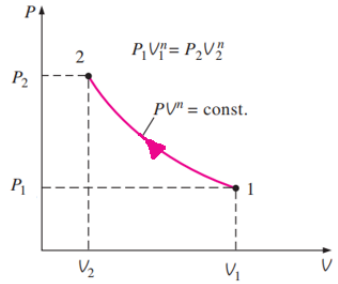
$$\boxed{W = 51.04\ kJ}$$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

EXAMPLE 2.3: A gas in a piston–cylinder assembly undergoes a quasistatic process for which the relationship between pressure and volume is $pV^2 = constant$. The initial pressure is 1 bar, the initial volume is 0.1 m^3, and the final pressure is 9 bar. Determine (a) the final volume, in m^3, and (b) the work for the process, in kJ.







The final volume:

$$P_1V_1^2 = P_2V_2^2 \rightarrow 1 \times 0.1^2 = 9 \times V_2^2 \rightarrow V_2 = 0.0333\ m^3$$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-n}\,dV = C\frac{V_2^{-n+1} - V_1^{-n+1}}{-n+1} = \frac{P_2V_2 - P_1V_1}{1-n} \quad \text{(kJ)} \qquad n \neq 1$$

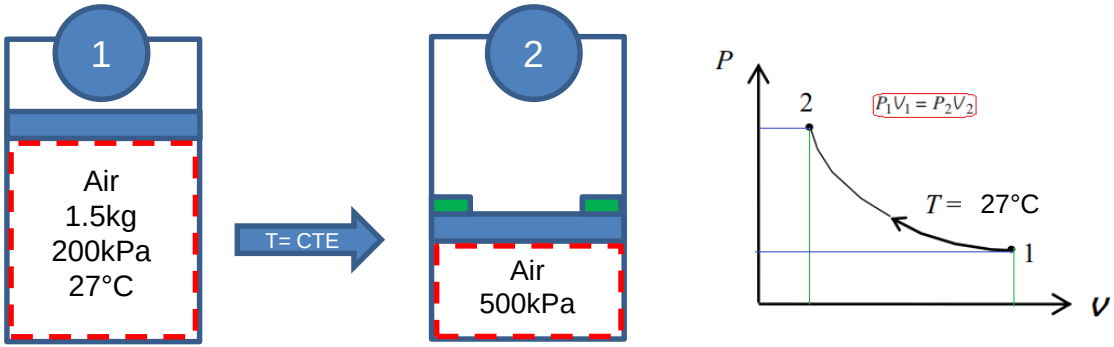
$$W = \frac{900 \times 0.0333 - 100 \times 0.1}{1-2} = -19.97\ kJ$$

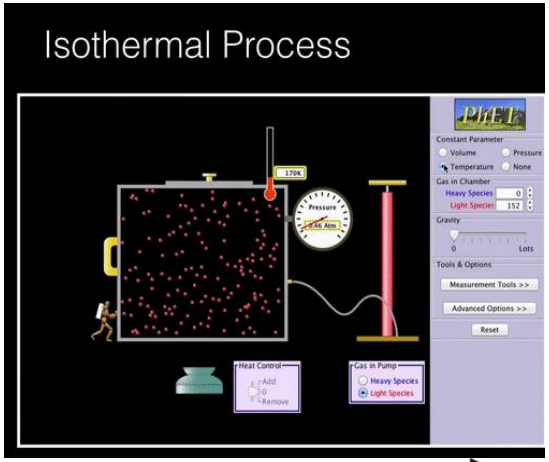
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

EXAMPLE 3.1: A mass of 1.5 kg of air(ideal gas) at 200 kPa and 27°C is contained in a frictionless piston–cylinder device. The air is now slowly (reversible) compressed to a final pressure of 500 kPa. During the process, heat is transferred from the air such that the temperature inside the cylinder remains constant. Calculate the work input during this process (**kJ**).

- Air in a cylinder is compressed at constant temperature until its pressure rises to a specified value.
- The boundary work done during this process is to be determined.
- ***Assumptions*** **1** The process is quasi-equilibrium. **2** Air is an ideal gas.
- ***Properties*** The gas constant of air is $\bar{R}/M = 0.287$ kJ/kg.K

$$Pv = (\bar{R}/M)T$$





UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

The quasi-static isothermal process, the work is:

$$W = \int_1^2 PdV = \int_1^2 \frac{m(\bar{R}/M)T}{V} dV = m(\bar{R}/M)T \ln \frac{V_2}{V_1}$$

The isothermal process:

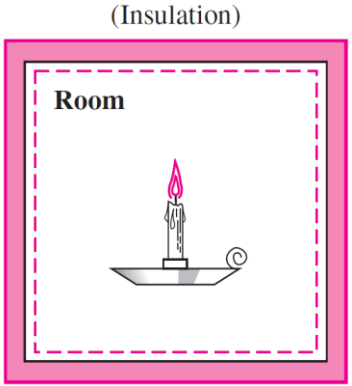
$$P_1V_1 = P_2V_2 \rightarrow \frac{V_2}{V_1} = \frac{P_1}{P_2}$$

Replacing:

$$W = 1.5 \times 0.287 \times (27 + 273.15) \times \ln \frac{200}{500} \Rightarrow W = -118.3981\ kJ$$

Burning of a Candle in an Insulated Room

A candle is burning in a well-insulated room. Taking the room (the air plus the candle) as the system, determine **(*a*) if there is any heat transfer during this burning process** and **(*b*) if there is any change in the internal energy of the system.**



Analysis

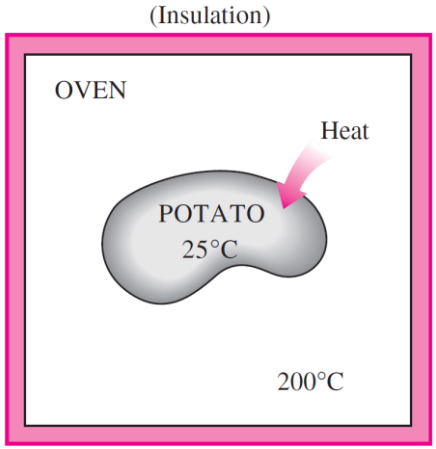
(*a*) The interior surfaces of the room form the system boundary, as indicated by the dashed lines in the Fig. Heat is recognized as it crosses the boundaries. Since the room is well insulated, we have an adiabatic system and no heat will pass through the boundaries. Therefore, $Q = 0$ for this process.

(*b*) The internal energy involves energies that exist in various forms (sensible, latent, chemical, nuclear). During the process just described, part of the chemical energy is converted to sensible energy. Since there is no increase or decrease in the total internal energy of the system, $\Delta U = 0$ for this process.

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Heating of a Potato in an Oven

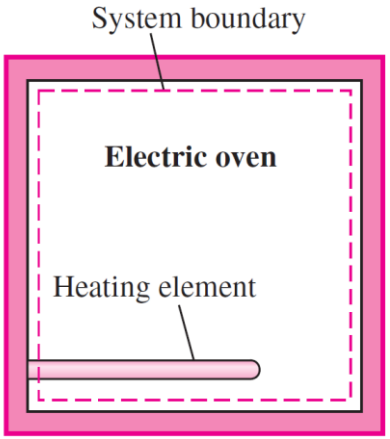
A potato initially at room temperature (25°C) is being baked in an oven that is maintained at 200°C, as shown in the Fig. **Is there any heat transfer during this baking process?**



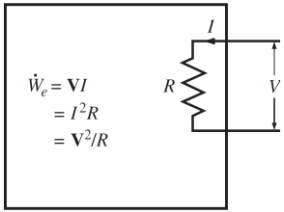
Analysis This is not a well-defined problem since the system is not specified. Let us assume that we are observing the potato, which will be our system. Then the skin of the potato can be viewed as the system boundary. Part of the energy in the oven will pass through the skin to the potato. Since the driving force for this energy transfer is a temperature difference, this is a heat transfer process.

Heating of an Oven by Work/heat Transfer

A well-insulated electric oven is being heated through its heating element. If the entire oven, including the heating element, is taken to be the system, **determine whether this is a heat or work interaction.**



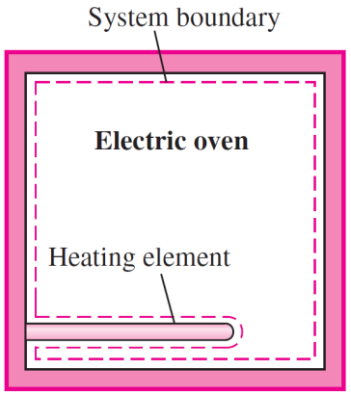
Analysis For this problem, the interior surfaces of the oven form the system boundary, as shown in the Fig. The energy content of the oven obviously increases during this process, as evidenced by a rise in temperature. This energy transfer to the oven is not caused by a temperature difference between the oven and the surrounding air. Instead, it is caused by *electrons* crossing the system boundary and thus doing work. Therefore, **this is a work interaction.**



UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Heating of an Oven by Work/heat Transfer

If the system is taken as only the air in the oven without the heating element. **Determine whether this is a heat or work interaction.**



Analysis This time, the system boundary will include the outer surface of the heating element and will not cut through it, as shown in Fig. Therefore, no electrons will be crossing the system boundary at any point. Instead, the energy generated in the interior of the heating element will be transferred to the air around it as a result of the temperature difference between the heating element and the air in the oven. Therefore, this is a heat transfer process.

Discussion For both cases, the amount of energy transfer to the air is the same. These two examples show that an energy transfer can be heat or work, depending on how the system is selected.


UTEC
UNIVERSIDAD DE INGENIERÍA
Y TECNOLOGÍA
Thanks!